

CAF awarded Centurylink's Optical Access Network for Lagrange, IN

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Abstract:

In today's digital age, access to reliable and affordable internet is crucial for economic development, education, and overall quality of life. This paper explores the challenges and solutions associated with providing cost-effective internet services to the rural community of LaGrange, Indiana. Funded by the government through the Connect America Fund and awarded to CenturyLink, this initiative was deployed by the professional services team of network system engineers at Calix Inc. We analyzed the current state of internet infrastructure in LaGrange, identifying key barriers, high service costs, and technological constraints. Through a comprehensive review of existing models and case studies, we proposed a multi-faceted approach that included the deployment of low-cost technologies and optical access networks. Our findings suggested that leveraging these strategies would significantly improve internet accessibility for residents of this town. The paper concludes with recommendations for policymakers and stakeholders to support the implementation of these solutions, ultimately aiming to bridge the digital divide and foster inclusive growth in LaGrange.

Keywords: fiber, outside plant, inside plant.

I. INTRODUCTION

Reliable and affordable access to high-speed internet is increasingly recognized as a fundamental requirement for socio-economic development in the modern era. Yet, many rural communities remain underserved due to significant infrastructural and financial barriers. Investments on high-speed broadband infrastructure can foster the agricultural sector through different mechanisms [1]. ISPs are unlikely to invest millions building infrastructure in a town of 2,000 people. Wireless and satellite options are too costly for families earning an average of \$30,000. While DSL is cheaper, infrastructure costs don't justify the investment. LaGrange, Indiana, exemplified these issues with limited affordable and reliable internet or telephone service. Such disparities hinder educational opportunities, healthcare accessibility, business growth, and overall quality of life for rural residents. This paper explores the infrastructure as built, analyzes current technological barriers, and implements scalable access network to generate broadband and affordability in a low-density community.

II. OUTSIDE PLANT (OSP)

A. Site surveys

Environmental factors can significantly impact rural broadband deployment. Seasonal weather conditions, such as heavy snowfall, flooding, or extreme temperatures, can delay construction and pose risks to the integrity of the infrastructure. These conditions can also increase maintenance costs and complicate long-term upkeep [5]. The OSP team performed an initial inspection to assess the site topology and identify potential physical obstructions or right-of-way (ROW) issues. They pinpointed critical locations such as handholes, manholes, and potential fiber distribution hubs (FDHs). The OSP team compiled all relevant project documentation, including GIS data, CAD drawings, and existing OSP records. The team established clear survey objectives, specifying the scope of work, including fiber routes, splice points, and network

termination locations. Engineers utilized electronic distance measurement (EDM) tools to accurately measure distances between key points, ensuring precise fiber route planning. High-resolution images of key points and potential obstacles were captured to provide visual references for network design. The team assessed the condition and capacity of existing infrastructure, including utility poles, conduits, and ducts, to determine their suitability for new fiber deployment. Governments can streamline regulatory processes, such as permitting and right-of-way access, to facilitate faster and more efficient broadband deployment [2]. All survey documentation was archived in a secure and accessible format for future reference and regulatory compliance.

B. Dark fiber installation and OSP site builds:

- a. *Fiber Build 48 FO FOR ROUTE 1 – OSP project N. 111505 – PL 12,600’ 48FO – \$34,200*
 - i. *S 050 W* - Placed approximately 4,700’ of 48 FO from the LGRNIN-A-R2-100-1.2X Remote to the new Calix E3-48 overlay node at pedestal 2-400-4. Spliced and tested continuity on a minimum of two fiber strands back to the LGRNIN-A-R2-100-1.2X Remote. This device needed to be line powered from available pairs within RO2, 785-800 from the LGRNIN-A-R2-100-1.2X Remote.
 - ii. *W 450 S* - Placed approximately 7,800’ of 48 FO from the new Calix E3-48 overlay node at pedestal 2-400-4 to the new Calix E3-48 overlay node at pedestal 2-401-7. Spliced and tested continuity on a minimum of two fiber strands back to the LGRNIN-A-R2-100-1.2X Remote. This device was local powered.
 - iii. *E 450 S* - Placed approximately 100’ of 48 FO from the splice point IPID# 18291 to the new Calix E3-48 overlay node at pedestal 2-200-22. Spliced and tested continuity on a minimum of two fiber strands back to the LGRNIN-A-R2-100-1.2X Remote. This device was line powered from available pairs within RO2, 1-175 from the LGRNIN-A-R2-100-1.2X Remote.
- b. *Fiber Build 48 FO FOR ROUTE 2 – OSP Project: N.146089 – PL 5,900’ 48FO – \$35,400*
 - i. *E 200 S* - Placed approximately 5,900’ of 48 FO from the LGRNIN-A-R3-100-XC1 remote to the new Calix E3-48 overlay node at pedestal 3-400-4. Spliced and tested continuity on a minimum of two fiber strands back to the LGRNIN-A-R3-100-XC1 remote. This device was line powered from available pairs within RO3, 51-100 from the LGRNIN-A-R3-100-XC1 remote.
- c. *Fiber Build 48 FO FOR ROUTE 3 – OSP Project: N.146096 – PL 8,200’ 48FO – \$49,200*
 - i. *E 100 S* – Placed approximately 8,200’ of 48 FO from the LGRNIN-A-R4-400-PD1X remote to the new Calix E3-48 overlay node at pedestal 4-400-10. Spliced and tested continuity on a minimum of two fiber strands back to the LGRNIN-A-R4-400-PD1X remote. This device was line powered from available pairs within RO4, 276-290 from the LGRNIN-A-R4-400-PD1X remote.
- d. *Fiber Build 48 FO FOR ROUTE 4 – OSP Project: N.146097 – PL 17,100’ 96FO – \$102,600*
 - i. *LGRNIN-A-R5-100-PD1X* - Placed 17,100’ of 96 FO from the LGRNIN-A-R6-100-PD1X remote, to the new ODC 1000E at the existing LGRNIN-A-R5-100-PD1X remote. Spliced and tested continuity on a minimum of two fiber strands back to the LGRNIN-A-R6-100-PD1X remote. This device was local powered.

Table 1: Cost of New Fiber layout in LaGrange’s OSP infrastructure.

OSP Activity	Node Name	Fiber Footage	Fiber Size	OSP COST
	LGRNIN-F-01	0		\$0.00
	LGRNIN-A-R2-100-1.2X	0		\$0.00
	R02-4 S 00 EW	0		\$0.00
N.111505	R02-1 E 450 S	100		\$6000.00
N.111505	R02-2 S 050 W	4700	48	\$28,200.00

	LGRNIN-A-R3-100-XC1	0		\$0.00
	R03-1 S 400 E(2)	0		\$0.00
N.146089	R03-2 E 200 S	5900	48	\$35,400.00
	LGRNIN-A-R4-400-PD1X	0		\$0.00
	R04-1 S 750 E(1)	0	48	\$0.00
	R04-2 S 750 E(2)		48	\$0.00
N.146096	R04-3 E 100 S	8200	48	\$49,200.00
N.146097	LGRNIN-A-R5-100-PD1X	17100	96	\$102,600.00

For all except premises applications, fiber is the communications medium of choice, since its greater distance and bandwidth capabilities make it either the only choice or considerably less expensive than copper or wireless. Only inside buildings is there a choice to be made, and that choice is affected by economics, network architecture and the tradition of using copper inside buildings [4].

III. INSIDE PLANT (ISP)

Central Office (CO) is a building structure and a facility for a Broadband Service Provider (BSP) to house the switches, routers, panels, and cables necessary for managing data, voice and video services to a community or a small town. The physical cabling and supporting infrastructure within the CO is referred to as Inside Plant (ISP). It includes all the equipment necessary to connect and manage the internal network.



Fig. 1. The Central Office for CenturyLink in LaGrange, Indiana

A. Specifications Book

The engineers at Calix, in collaboration with the CenturyLink ISP team, developed and maintained a comprehensive document detailing the tasks to be completed. This document not only outlined the scope of work but also delineated the responsibilities of both the Calix and CenturyLink engineering teams, including the reporting domains for their respective hours. The Spec Book serves as a dynamic and continuously evolving record, updated by project contributors with relevant values, quantities, measurements, and annotations necessary to fulfill requirements. For indoor applications, the convenience provided by wireless connections is often preferred, especially for personal devices and wearable sensors. At the backhaul, optical fiber is the technology of choice for most Internet service providers (ISPs) and wireless communications carriers. The deployment remains relatively expensive, thus wireless alternatives (e.g., fixed wireless, cellular, and satellite) may be considered [3].

a. Labor Codes – The Spec Book contained all labor codes to be captured depending on the teams involved and the overall scope of work. This project utilized labor codes as seen in the table below:

Table 2: Record of all labor codes applicable to LaGrange’s ISP infrastructure.

Mnemonic	WBS Element	Description
C.01	EENG	COMPANY ENGINEERING
C.02	EISP	COMPANY INSPECTION
C.06	XDSL	MATERIAL MNEMONIC
C.07 / C.13	INDI	SERVICE PACKAGES
C.04	ELCW	NATIONAL LOAD TEAM
C.05 / C.08	SLCW	STRUCTURE LOAD TEAM
C.09	NABB	COMPANY ONA

b. As built – The Spec Book contained details on the CO network connectivity as it stood prior to start of the project. It also projected the nodes and shelves to be included as part of the network implementation as seen in the below in the connectivity diagram for Lagrange. The nodes representing with a dotted line connection were planned whereas the nodes represented with a solid line connection were part of the as built network in Lagrange, IN.

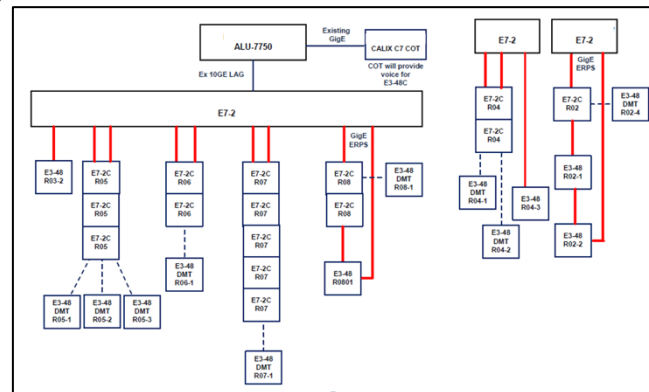


Fig. 2. The connectivity diagram for CenturyLink in LaGrange, IN.

c. ISP Form – Every node that is installed in the field connected back to the Central Office in a hub and spoke formation, or, a N:1 network connectivity. The Spec Book carried details of every remote Calix DSLAM (Digital Subscriber Line Access Multiplexer) device. This meant every remote node required a dedicated CO switch and an Ethernet port to implement the fiber connection. Every node in CenturyLink’s network was assigned a CLLI (Common Language Location Identification) code.

IV. NETWORK DESIGN ENGINEERING

Calix was solely responsible for creating and maintaining the optical network architecture based on CenturyLink’s existing network design. The access network structure comprised two main components: the central office and the remote nodes. This phase represented one of the most complex elements of the project, relying significantly on the precision of data recorded in ISP and OSP documentation. These records detailed all remote and central office devices, as well as connections to uplink switches, relay racks (RR), and their respective ports. PON networks provide the necessary technological foundations for the transmission and distribution of signals over optical access networks, facilitating the integration of multiple services on a single channel. This approach is crucial to address growing connectivity demands, enabling optical networks not only to meet current needs, but also to anticipate and adapt to future technological challenges [6].

Central Office network redesign – This design was emphasized on cultivating the existing network elements in CenturyLink’s Central Office and adding new parts such as SFPs (Small Form factor Pluggable), fibers, splitters, patch panels, power cables and shelf racks based on the Calix engineer’s networking knowledge, skills to deploy Calix switches and an experience creating Ethernet based services.

[illegible]

5

Remote node design – The Calix E3-48 DSLAMs were designed to be installed and turned up at various locations across Lagrange in an attempt to provide service to majority population of the town. The data captured in OSP site surveys and ISP port assignments was fused together into a network architecture that provided a N:1 connection to each of the remote nodes. The remote nodes where dark fiber was laid by CenturyLink were fed via the CO patch panel as an ethernet uplink.

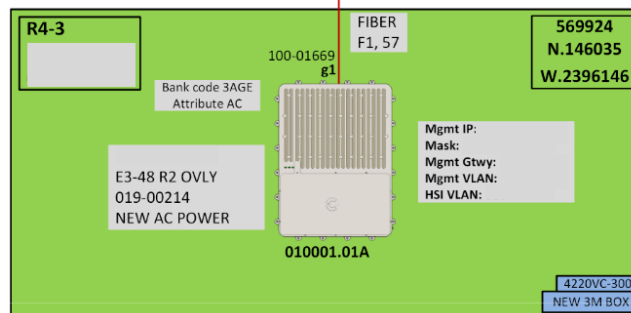


Fig. 5. A Calix E3-48 shelf in a fiber uplink architecture for deployment of remote node.

The remote nodes not served via dark fiber were linked via a uplink made of bonded copper trunk solution that uses Discrete Multi-Tone (DMT) modulation to aggregate multiple copper pairs into a single high-bandwidth uplink.

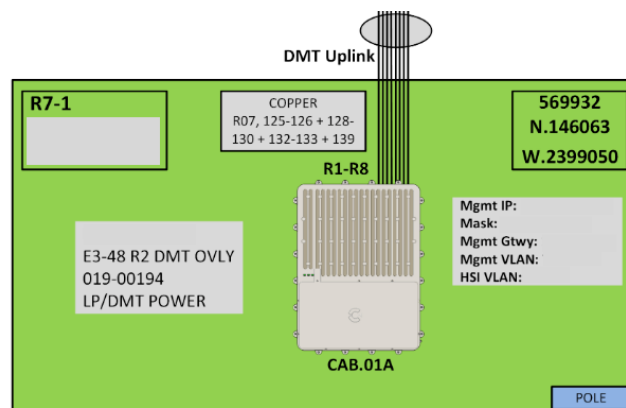


Fig. 6. A Calix E3-48 shelf in a DMT uplink architecture for deployment of remote node.

Remote cabinet - The Calix E7 VDSL-48C shelves were designed to be installed into remote cabinets as a point of uplink to serve remote nodes that were not able to be served a connection directly from the CO shelf. The data captured in OSP site surveys and ISP port assignments was fused together into a network architecture that provided a 1:1 connection to the CO via a 1G Active-Standby LAG connection over fiber, and another 1:1 connection to the remote node via DMT copper trunk.

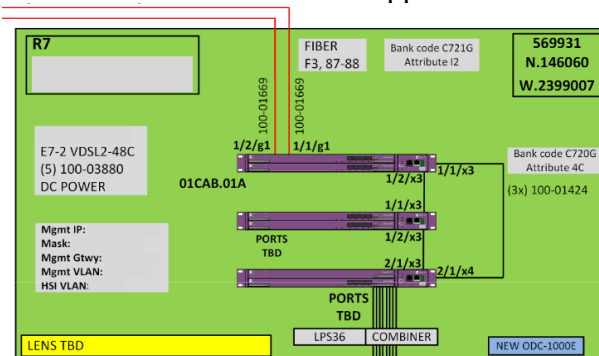


Fig. 7. A Calix E7 VDSL-48C shelf in a remote cabinet architecture served via a 1G LAG and serving down a DMT uplink to a remote node.

V. TURN UP, TESTING AND VALIDATION

Once the full network architecture is ready, all details required for installations are recorded. This includes fiber strands, ports on the uplink switches, ports on the core routers, VLAN tags to be used for each of the services being turned up at the node, IP address assignments and RADIUS server configuration to enable PPPoE (Point to point over Ethernet) connection to the core.

There are various portals and databases across CenturyLink and Calix which recorded this data. It was readily available based on a simple CLI code look up of the site where installation was scheduled. The field technician would enter a CLI code and all electrical cabling, fiber, SFP and cabinet details would be available due to the thorough nature of the network architecture by the Calix engineer. The field technician called Calix engineers from the field after the initial installation was completed. This included writing a basic configuration file that provisioned the uplink port on the remote shelf to be able to authenticate to the RADIUS server, obtain an IP address and get a VLAN membership that would enable IP traffic routing to the core network.

Calix engineer's first task was to ping the IP address from their VPN (Virtual Private Network) and make sure the connectivity is true. Then log in to the Calix E3 and E7 shelf and run commands to read the light levels on the remote as well as uplink (host) shelf. A fiber connection was good if the light level reading was in the -5dB to -15dB range at the receiving SFP.

A. High dB levels:

If the receiving SFP has a light reading higher than -5dB, then Calix engineer would request the technician to add a 3dB or 5dB padding to the fiber. This would help getting the light reading within the desired range. In certain cases where the remote node was too close to the CO, two or multiple paddings were required to obtain desired light levels.

B. Low dB levels:

If the receiving SFP has a light reading lower than -15dB, then Calix engineer would request the technician to drive up to the CO and swap out the assigned SFP with a long distance SFP on the uplink port. Using a long distance SFP would enable getting a better light reading at the remote node's SFP.

C. No light on fiber:

If the receiving SFP showed no light reading, then it required troubleshooting steps to be followed by the Calix engineer.

1. Check if the Ethernet ports on remote and host are enabled.
2. Check if both Ethernet ports detected SFP in the port.
3. Using the field tech's light meter check if a reading is seen at the fiber patch panel. If no, skip to 6.
4. Plug in the SFP at the remote location in ethernet port GE2. The default port used for all turn ups was GE1.
5. Swap out the SFP at the remote location with a spare SFP of the same part number.
6. Steps 2-6 are repeated at the host location if there was no light reading at this end as well.
7. Finally, the conclusion was to audit the fiber splicing in the field and a ticket was raised to CenturyLink field team to assess.

Calix engineer's then ran commands on the remote node to further configure bandwidth profiles, VLAN attributes and any service related objects to the DSL ports 1-48. The Calix engineer upgraded the remote shelf to the latest software version and checked for any alarms related to power or fiber. To prepare for testing, data service was provisioned on any ports of the remote shelf by running service commands.

The field technician connected a DSL modem to the port provisioned by Calix engineer and get authenticated via PPPoE. After service was activated, a speed test was conducted to the CenturyLink Ookla server. The speed test was repeated 5 times and all results were recorded, to finally take an average of the tests. The average was required to be within 80% of the assigned download speed.

Table 4. Assigned download and upload speeds and testing speeds average targeted at 80%.

Down	60.0M						
Up	5.0M						
Test	1	2	3	4	5	Avg.	%
Down	62.37	62.46	62.48	62.31	62.38	62.4	104
Up	5.21	5.1	5.05	5.16	5.21	5.15	102.9

Validation was the last step to be conducted by Calix engineering, however this would be conducted by a peer of the engineer that participated in the turn up and testing. This provided a layer of peer review and double checking the configuration. The steps followed for a remote site's validation were:

1. Check the speed test record.
2. Check software version.
3. Check alarms on the shelf.
4. Check configured VLANs for services.
5. Make sure data service VLAN was on the correct (uplink) port.
6. Check time and NTP configuration.
7. Check hardware versions in Calix E3-48 R1/R2 were accurately marked on the portal.
8. Check if circuit id matched across all portals.
9. Change the Functional status in CenturyLink's portal from pending to monitored.

The output of all commands run to the remote and host shelves was logged in a repository for future reference.

VI. PROJECT CLOSURE

At the end of validation, the project notes, spec book and other CRM portals across Calix and Centurylink were updated to reflect a successful turn up of a site. Once all remote sites in a town were turned up, tested and validated, the project was considered as successfully completed. In the Lagrange project a grand total of 20 remote sites were successfully built from the ground up, and 3 existing host sites had additional operations carried out. The overall expansion of CenturyLink's ISP reachability dramatically increased from a handful of subscribers to the whole town within touching distance of a good DSL connection at affordable prices. All speed test recordings that were submitted in a repository were uploaded to the FCC for a final approval after the project was completed. The FCC was a final authority that certified the recordings and validated that Calix and CenturyLink had successfully adhered to all their standards. Lagrange, IN was a highly successful CAF implemented town that enabled the average population access to high speed internet at affordable cost.

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